

Inhibitive properties of plant extract (*Acalypha indica* L.) on mild steel corrosion in 1N Phosphoric acid

M.Sivaraju¹, K. Kannan^{2*}

¹Department of Chemistry, Muthayammal Engineering College, Rasipuram, India

^{2*}Department of Chemistry, Government College of Engineering, Salem-636 011, India

*Corres.author: vsathanitharan@gmail.com; kannan_k2002@yahoo.co.in

Abstract: The inhibition effect of *Acalypha indica* L. alcoholic extract (AIAE) on mild steel corrosion in 1N phosphoric acid has been studied by mass loss and polarization techniques between 303 K and 333K. The inhibition efficiency increased with increase in concentration of plant extract. The corrosion rate increased with increase in temperature and decreased with increase in concentration of inhibitor compared to blank. The adsorption of inhibitor on mild steel surface has been found to obey Temkin's adsorption isotherm. Potentiostatic polarization results revealed that *Tribulus terrestris* L extract act as mixed type inhibitor. The values of activation energy (E_a), free energy of adsorption (ΔG_{ads}), heat of adsorption (Q_{ads}), enthalpy of adsorption (ΔH) and entropy of adsorption (ΔS) were calculated. Surface analysis (FT-IR and SEM) was also carried out to establish the mechanism of corrosion inhibitor on mild steel corrosion in phosphoric acid medium.

Keywords: Mild Steel; Phosphoric acid; Corrosion inhibition; Temkin's adsorption isotherm; Potentiostatic polarization; FT-IR; SEM; *Acalypha indica* L alcoholic extract (AIAE).

Introduction

Phosphoric acid is a major chemical product, which has many important uses, especially in the production of fertilizers. Most of the acid is produced from phosphate rock by wet process. Generally nickel-base alloys and stainless steel are frequently used in many parts of the wet process and a considerable quantity of data has been published about the resistance of these materials to corrosion by phosphoric acid solution^{1) - 4)}. Most of the previous studies were focused on the inhibition of stainless steel or chromium-nickel steel in hydrochloric acid or phosphoric acid solutions using organic compounds containing nitrogen, sulphur and oxygen atoms as corrosion inhibitors^{5) , 6)}. The corrosion inhibiting property of these compounds is attributed to their molecular structure. These compounds contain π electrons and heteroatom, which induce greater adsorption of the inhibition molecules onto the mild steel surface.

Because of the toxic nature and high cost of some chemicals currently in use, it is necessary to develop environmentally acceptable and less expensive

inhibitors. Natural products can be considered as a good source for this purpose. Extracts of naturally occurring products contain mixture of compounds and are biodegradable in nature, these compounds having nitrogen and sulphur as constituent atoms are studied as corrosion inhibitor in HCl medium⁷⁾. G.Gunasekaran and L.R.Chaghan studied the inhibition effect of *Zenthoxylum alatum* on the corrosion of mild steel in Phosphoric acid medium⁸⁾. A.M.Abel-Gaber and co-workers studied inhibitive action of some plant extracts *Nigella Sativa*.L (Black cumin), *Phaseolus vulgrais*.L (Kidney bean) and *Cymbopogon proximus* (Halfabar) on the corrosion of mild steel in sulphuric acid medium⁹⁾. Several works have been reported using such economical plant leaves extract of *Azadirachta indica* for mild steel in H_2SO_4 ¹⁰⁾, leaves extract of *Nypa fruticand wurmb*¹¹⁾ and *occinium viridis*¹²⁾, acid extract of *Allium sativum* (Garlic)¹³⁾ *Foenum Graecum*¹⁴⁾, aqueous extract of *Lawsonia inermis* (Henna)¹⁵⁾ and Carboxymethylchitoson¹⁶⁾ as inhibitors for mild steel in HCl medium. Literature survey revealed that not much work was done on the corrosion inhibition of

mild steel in phosphoric acid solutions using naturally available plant extracts.

Acalypha indica L, is a member of the Euphorbiaceae family, is a small annual Shrub, which generally distributed throughout the plains of India. It has been reported to be useful in treating Antidote, snakebite, asthma, Pneumonia and other several other ailments. Extracts of this plant have been used traditionally in treating variety of diseases including hypertension, coronary heart diseases, ocular inflammation and infertility in both sexes.

The phytochemical components of AIAE has been extensively studied and it is known to have steroids, carbohydrates, alkaloids compounds^{17) -18)}, Flavonoids (Chrysin & Glucanin)¹⁹⁾, tannins²⁰⁾. These compounds have been known for their medicinal properties like antifungal, antibacterial, antioxidant and most likely responsible for inhibiting corrosion.

So, in this present investigation, the corrosion of mild steel in 1N phosphoric acid solution in the absence and presence of AIAE at 303 to 333K has been studied by mass loss and polarization techniques. It is aimed to predict the corrosion rate, inhibition efficiency on mild steel corrosion and the thermodynamic feasibility of inhibition via surface coverage on mild steel by adsorbed AIAE at various temperatures. The adsorption characteristic of AIAE was studied in order to access the mechanism of corrosion inhibition and the adsorption isotherm (s).

EXPERIMENTAL

1. Preparation of specimens:

Mild steel specimens were cut to size of 5 cm x 1.5 cm from the mild steel sheets having the following percentage composition as shown below. The surface of specimens were polished with emery papers ranging from 110 to 410 grades and degreased with trichloroethylene specimens were dried and stored in vacuum desiccators containing silicagel.

2. Preparation of plant extract:

Water extract of *Tribulus terrestris* .L was prepared by the aerial part of plant collected and dried in air and then Grained. 50g of grained powder subjected to Soxhlet extraction using methanol (95%). The solvent can be removed by boiled at constant temperature at 40°C in vacuum evaporator, finally the residue of AIAE was collected. From the AIAE

residue the various concentration of inhibitor solution (1, 2, 3, 4, and, 5 mgs) was prepared. All the solutions were prepared with AR grade chemicals in double distilled water.

3. Weight loss measurement:

Polished specimens were initially weighed in an electronic balance. After that the specimens were suspended with the help of PTFE threads and glass rod in 100ml beaker containing acid in the presence and absence of AIAE. The specimens were removed after 4 hours exposure period, washed with water to remove any corrosion products and finally washed with acetone. After that they were dried and reweighed. Mass loss measurements were carried out in 1N phosphoric acid with AIAE in the concentration range of 1mgs to 5 mgs as inhibitors and the temperature between 303 K and 333 K for an immersion period of 4 hours. Mass loss measurements were performed as per ASTM method described previously^{21) - 22)}.

4. Potentiostatic Polarization measurements

Polarization measurements were carried out in a conventional three-electrode cell. Mild steel strips coated with lacquer except for an exposed area of 1 cm² were used as the working electrode. The saturated calomel electrode and the platinum foil were used as reference and counter electrodes respectively. The potentiostatic polarization measurement was carried out using BAS – 100, a model instrument. The potential of the test electrode was measured with respect to SCE, platinum electrode was used as auxiliary electrode and the experiment was carried out at 303K to 333K.

5. Surface analysis:

The mild steel specimens were exposed in 100 ml of 1N Phosphoric acid solution having 5 mgs of plant extract for 3 hours at room temperature and washed with distilled water then dried. The nature of film formed on the surface of the metal specimens was analyzed by FT-IR and SEM. The dried specimens were scratched off and the resultant powder mixed with KBr (1:100 ratio) to prepare pellets, then the pellets was introduced into Fourier Transfer Infra-Red spectrophotometer FT-IR,8400's SHIMADZU, Japan to analyse the sample.

Composition of mild steel:

Element	Fe	Ni	Mo	Cr	S	P	Si	Mn	C
Composition (%)	99.686	0.013	0.015	0.043	0.014	0.009	0.007	0.196	0.017

RESULTS AND DISCUSSION

Mass loss Studies

Table I shows the value of inhibition efficiency [IE%], surface coverage (θ) and corrosion rate obtained at different concentration of the inhibitors in 1N phosphoric acid solution for an immersion period of 3 hours. From the mass loss value, the inhibition efficiency [IE%] and surface coverage (θ) were calculated using the following equation²³.

$$IE(\%) = \frac{W_u - W_i}{W_u} \times 100 \quad [1]$$

$$\theta = \frac{W_u - W_i}{W_u} \quad [2]$$

Where W_u and W_i are the corrosion rates for mild steel in the absence and presence of inhibitor respectively at the same temperature.

It could be seen from the table that the addition of inhibitor to the acid had reduced the corrosion rate. The inhibition efficiency increased with increase in concentration of inhibitors and decreased with increase the temperature from 303 K to 333 K in 1N Phosphoric acid.

THERMODYNAMIC CONSIDERATION

Energy of activation (E_a):

Table II shows that the calculated values of activation energy (E_a) for mild steel corrosion in 1N phosphoric acid with and without inhibitor from 303K to 333K. Energy of activation (E_a) was calculated from the slopes of plots of $\log p$ versus $1/T$ in fig-1 and also calculated from Arrhenius equation²⁴.

$$\log \frac{P_2}{P_1} = \frac{E_a}{2.303R} \left[\frac{1}{T_1} - \frac{1}{T_2} \right] \quad [3]$$

Where P_1 and P_2 are the corrosion rates at temperatures T_1 and T_2 respectively. The E_a values were found to be 32.26KJ/mole and 14.95 KJ/mole in 1N phosphoric acid with and without AIAE respectively.

The addition of plant extract increases the activation energy as reported by G.Gunasekaran and L.R.Chaughan for metal dissolution reaction indicating that this plant extract hinders metal dissolution²⁵. F.Bentiss et.al, explained that the E_a value increased in the presence of plant extract may be interpreted as physical adsorption (weakening) that occurs in the first stage, that is important because it is the proceeding stage of chemisorption of plant extract on mild steel²⁶. But T.Szauer and A.Brand revealed that the increase in E_a can be attributed to an appreciable decrease in the adsorption of the inhibitor on mild steel surface with increase in temperature. A corresponding increase in the corrosion rate occurs because the greater area of

the metal that is frequently exposed to acid environment²⁷.

Table II shows that the E_a values for 1N phosphoric acid containing AIAE are found to be higher than that of without inhibitor. These higher values of E_a indicate that the addition of plant extract hinders metal dissolution and also indicate that, decrease in the adsorption of inhibitor on mild steel surface with increase in temperature. The E_a values are calculated from the slopes of Arrhenius plot and by using equation-3 are approximately almost similar.

Free energy of adsorption:

The free energy of adsorption (ΔG_{ads}) at different temperatures was calculated from the following equation²⁴.

$$\Delta G_{(ads)} = -RT \ln (55.5 K) \quad [4]$$

Where K is given by

$$K = \frac{\theta}{C(1-\theta)}$$

Where θ is surface coverage on the metal surface, C is concentration of inhibitor in mole/lit and K is equilibrium constant. 55.5 is concentration of water (mol. /lit)

M.Boukka et.al, explained generally the values of ΔG_{ads} upto -20 KJ/mole are consistent with characteristic interaction between charged molecules and charged metal surface (physisorption). While those around -40 KJ/mole or higher²⁶-²⁸) or smaller¹⁷-²⁹) are associated with chemisorption¹⁴) as a result of sharing or transferring of electrons from organic molecules to the metal surface.

The free energy of adsorption (ΔG_{ads}) in 1N phosphoric acid with AIAE on mild steel calculated from the equation (4) from 303K to 333K. From table II the negative free energy values (ΔG_{ads}) ranging from -31.00 to -28.27KJ/mole indicate that the adsorption of the inhibitor is spontaneous and also adsorption of plant extract (AIAE) on mild steel is chemically adsorbed in phosphoric acid medium attributed to the donation of π electron by aromatic rings or Non-bonding electron pair of compounds (hetero atoms) present in plant extract.

Heat of adsorption (Q_{ads}):

The values of heat of adsorption Q_{ads} were calculated using the following equation³⁰.

$$Q_{ads} = 2.303R \log \left[\frac{\theta_2}{1-\theta_2} \right] - \left[\frac{\theta_1}{1-\theta_1} \right] \times \frac{T_1 T_2}{T_2 - T_1} \quad \dots [5]$$

Where θ_1 and θ_2 are degrees of surface coverage at temperature T_1 and T_2 by the different additives.

E.E.Oguzie explained that the negative values of Q_{ads} also signify that the degree of surface coverage decreased with rise in temperature and positive values

of Q_{ads} means the physical adsorption equilibrium is usually rapid and the process readily reversible whereas in chemisorption, the occurrence of chemical reaction at the metal surface makes the process relatively slow and not readily reversible³⁰⁾. From table II it is evident that in all the cases, the Q_{ads} values are ranging from 2.38 to 21.00 KJ/mole with AIAE. The higher negative values of heat of adsorption also show that the inhibition efficiency decreased with rise in temperature.

The enthalpy of adsorption (ΔH) and entropy of adsorption (ΔS)

The enthalpy of adsorption (ΔH) and entropy of adsorption (ΔS) were also calculated from the following equations^{31) - 32)}.

$$\Delta H^0 = E_a - RT \text{ ----- [6]}$$

$$\Delta G^0 = \Delta H^0 - T \Delta S^0 \text{ ----- [7]}$$

The thermodynamic data obtained in this study are shown in table –II. It could be seen from the table that the activation energy increased linearly with increasing the efficiency of inhibitor.

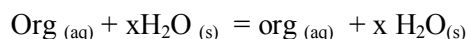
F.Bentiss et.al, revealed that the positive sign of enthalpies (ΔH) reflects the endothermic nature of the steel dissolution process, which means dissolution of mild steel in acid medium is difficult²⁶⁾. O.O. Adeyen and C.Montiealy et.al described that if the heat of adsorption (ΔH_{ads}) < 10 KJ/mole the adsorption is probably physisorption and if (ΔH_{ads}) > 10 KJ/mole the adsorption is probably chemisorption³³⁾. Therefore, the enthalpy of adsorption (ΔH_{ads}) values indicate that the plant extract strongly adsorbed on mild steel is chemisorption.

In authors view, the adsorption of inhibitor is not considered only physical or chemical adsorption phenomenon in this case. Physical adsorption that occurs in the first stage, then according to hard and soft acid base theory, inhibitors are chemisorbed on the surface of mild steel by sharing of an electron pair of hetero atoms present in plant extract with d-orbital of iron forming covalent bond, leading to the positive value of ΔH_{ads} ¹⁷⁾.

It's also observed that ΔS values increased with increase the efficiency of inhibitors. This is opposite to the expectation, since the adsorption is an exothermic process and is always accompanied by decrease in entropy. Ateya et. al.²⁴⁾⁻³⁴⁾ has described this situation as the adsorption of the organic compound leads to desorption of water molecules from the surface. While the adsorption process is believed to be exothermic and associated with a decrease in entropy of the solute, the opposite is true for the solvent. Therefore, this gain in entropy that accompanied the substitutional adsorption process is attributed to the increase in solvent entropy.

Adsorption isotherms

The electrochemical process on the metal surface are likely to be closely related to the adsorption of the inhibitors³⁵⁾ and the adsorption is known to depend on the chemical structure of the inhibitors^{36) -37)}. The adsorption of the inhibitors molecules from aqueous solutions can be regarded as quasi-substitution process³⁶⁾ between the organic compound in the aqueous phase, org (aq) and water molecules at the electrode surface, $H_2O_{(s)}$.



Where x (the size ratio) is the number of water molecules displaced by one molecule of inhibitor.

Adsorption isotherms are very important in determining the mechanism of organo-electrochemical reactions. The most frequently used are those of Langmuir, Frumkin, Parsons, Temkin, Flory –huggins and Bockris –Swinkels³⁸⁾⁻⁴⁰⁾. All these isotherms are of the general form:

$$f(\theta, x) \exp(-a\theta) = KC$$

Where $f(\theta, x)$ is the configurational factor that depends essentially on the physical model and assumptions underlying the derivation of the isotherm^[41].

The mechanism of inhibition of corrosion is generally believed to be due to the formation and maintenance of a protective film on the metal surface. The plot of surface coverage (θ) obtained by mass loss method versus log C at different concentrations of the inhibitors shows a straight line indicating that the adsorption of the inhibitor from acid on mild steel surface follows the Temkin's adsorption isotherm. This also points out that the corrosion inhibition by these compounds is being a result of their adsorption on the metal surface. Fig.2 shows the Temkin's adsorption isotherm plots for AIAE with 1N phosphoric acid.

FT-IR Analysis:

The peak values obtained from FT-IR analysis are shown in Table-III. The broad peaks between 3200cm^{-1} to 3500cm^{-1} assigned to the presence of a superficial absorbed water, stretching mode of an OH and/or $NH^9)$. The peaks at 2923 & 2858 corresponds to stretching vibration of aliphatic and aromatic C-H. The peaks at 1733, 1670, 1608, 1569, 1249, 1172 & 1042cm^{-1} corresponds to stretching vibration of C=O; $R_2C=N$; Aromatic substituted C=N, C=C (Aromatic ring), stretching vibration of ether linkage (C-O) and stretching vibration of C-O. This shows that the plant extract contains mixture of compounds. Almost all the peak observed for plant extract is also noticed on mild steel immersed in 1N phosphoric acid with 5mgs of plant extract as shown in Fig -4.

The stretching frequency of C=O and C-O shift from 1733 cm⁻¹ to 1718 cm⁻¹ and 1042 cm⁻¹ to 1020 cm⁻¹ due to electron cloud density shift from O atoms to co-ordinate with Fe²⁺ to form Iron plant extract complex [42-46]. The peaks at 1272 cm⁻¹ (P=O) 1018 cm⁻¹ (P-O-Fe) indicates Iron phosphate complex. Then the peaks between 400 and 700 cm⁻¹ are mainly due to Fe₂O₃⁸⁾.

Scanning Electron Microscope:

Surface of polished mild steel specimen immersed in 1N phosphoric acid in the presence of plant extract (5mgs) were examined using scanning electron microscope model JEOL6360, Japan. Fig 5a and 5b shows the surface photograph of mild steel specimens immersed in 1N phosphoric acid in the absence and presence of plant extract respectively. In the case of blank, the corroded metal surface with etched grain boundaries and corrosion products are clearly seen in fig 5a. But in the presence of plant extract there is formation of adsorbed layer of inhibitors on the metal surface as seen in fig 5b.

Potentiostatic Polarization studies

The Polarization behavior of mild steel functioning as cathode as well as anode in the test solution is shown in fig.3 for 1N phosphoric acid with AIAE extract at room temperature (303K). The electrochemical data obtained are shown in Table I. It is evident that AIAE bring about considerable polarization of cathode as well as anode. It was therefore inferred that the inhibitive action is of a mixed type. The non-constancy of Tafel slopes for different inhibitor concentration revealed that the inhibitor act through their interference in the mechanism of the corrosion processes at the cathode as well as anode. The i_{corr} values were decreased with increasing concentration of the inhibitors which indicate that the corrosion process is controlled by adding AIAE.

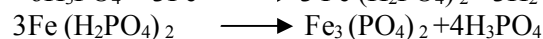
MECHANISM:

The composition and the structure of the films formed on iron remains subjects of continued interest from FTIR studies on the oxides of iron revealed the presence of Fe₂O₃ in solutions irrespective of the nature of the iron substrate.

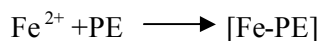
At the interface of iron and electrolyte, the dissolution of iron can be written as,



At medium and high concentrations of phosphoric acid, precipitation of iron-phosphate occurs at interface.



However, this precipitation can be weakly observed when the mild steel is treated with phosphoric acid solutions with low concentration. The formation of insoluble phosphate depends on the metal ions present in solutions at interface, concentration of metal ion in the solution and the reactivity of metal surface. G.Gunasekaran and L.R.Chauhan⁸⁾ explained that as soon as the plant extract interact with dissolving iron to form an organo-metal complex (Fe-PE) and forms a layer.



This layer reacts with phosphate ions to form a layer of FeHPO₄/FeH₂PO₄. This reaction takes place in series with the formation of Fe - PE, since it is mediated or catalyzed by this compound, as is observed by the increased rate of formation of iron phosphates. After certain period, the formation of iron phosphate results in a dense layer and formation of Fe-PE will less. This was reflected by FT-IR analysis of mild steel immersed in 1N phosphoric acid containing 5mgs of plant extract⁸⁾.

Table – I: The corrosion parameters for mild steel in 1N phosphoric acid with AIAE from Mass loss and polarization studies.

Temp (K)	Conc of (AIAE) (mgs)	Mass loss studies			Polarization measurement				
		Corrosion Rate (mmpy)	Surface coverage (θ)	Inhibition Efficiency (%)	E_{corr} Vs SCE (mv)	I_{corr} $\mu A/cm^2$	Tafel constant mv/decade		IE (%)
							b_a	$-b_c$	
303	Blank	159.2502	-----	-----	-460	260	55	110	-----
	1	39.8249	0.7499	74.99	-455	52	45	95	80.00
	2	27.2930	0.8286	82.86	-457	48	45	90	81.54
	3	21.0517	0.8678	86.78	-475	42	50	95	83.85
	4	15.3059	0.9039	90.39	-480	34	55	90	86.92
	5	7.6282	0.9521	95.21	-475	25	35	85	90.38
313	Blank	182.7291	-----	-----	-465	610	50	120	-----
	1	52.4560	0.7129	71.29	-455	225	45	117	63.11
	2	45.2241	0.7525	75.25	-460	202	40	100	66.89
	3	40.9642	0.7758	77.58	-477	156	45	90	74.43
	4	35.3669	0.8065	80.65	-465	125	35	90	79.51
	5	26.3023	0.8561	85.61	-480	110	40	85	81.97
323	Blank	217.0558	-----	-----	-475	1050	65	135	-----
	1	82.1761	0.6214	62.14	-475	515	60	110	50.95
	2	70.5852	0.6748	67.48	-470	440	60	98	58.10
	3	55.7252	0.7433	74.33	-465	340	60	105	67.62
	4	46.9578	0.7837	78.37	-475	235	55	100	77.62
	5	35.7137	0.8355	83.55	-475	245	52	95	76.67
333	Blank	271.7408	-----	-----	-480	1600	90	140	-----
	1	126.2114	0.5355	53.55	-470	782	83	135	51.13
	2	109.4690	0.5972	59.72	-460	765	81	125	52.19
	3	99.8100	0.6327	63.27	-475	605	75	125	62.19
	4	91.8351	0.6620	66.20	-480	510	70	110	68.13
	5	78.1639	0.7124	71.24	-482	472	75	105	70.50

Table –II: Thermodynamic parameters for mild steel corrosion in 1N phosphoric acid with AIAE.

Conc. of AIAE (mgs)	Ea (from eqn,1) KJ/Mol	Ea (from plot) KJ/Mol	-ΔG _{ads} KJ/Mole				Q _{ads}	ΔH KJ /mol	ΔS KJ /mol / k
			302K	313K	323K	333K			
Blank	14.95	15.60	-----	-----	-----	-----	-----	10.79	-----
1	32.26	35.36	30.29	30.79	30.67	30.64	2.38	28.10	0.1946
2	38.85	42.51	29.74	29.52	29.43	29.41	8.71	34.69	0.2123
3	43.53	45.28	29.49	28.80	29.24	28.71	12.46	39.37	0.2272
4	50.11	49.10	29.67	28.53	29.07	28.27	15.53	45.95	0.2484
5	65.08	59.54	31.00	28.88	29.38	28.30	21.00	60.92	0.2990

Table - III :FT-IR peak values for plant extract, mild steel in H₃PO₄, and mild steel in H₃PO₄ with Plant extract (AIAE).

FT-IR peak values			Possible groups	Ref. No
Mild steel in H ₃ PO ₄	Plant Extract (AIAE)	Mild steel in H ₃ PO ₄ with Plant extract		
-	3670-3550	3670-3550	Stretching mode of Non-bonded hydroxyl group	42,45
3000-3500	-	-	Stretching mode of O-H (from adsorbed water)	8,42
-	3342	3344	O-H/N-H (from plant extract)	8, 9
-	2923	2923	Aliphatic C-H	8, 9,45
-	2858	2852	Aromatic C-H	8, 9,45
-	1733	-	C=O (Lactone)	45,42
-	-	1718	Iron-plant extract complex	8,9
-	1670	1670	R ₂ C=N	8, 9,45
-	1608	1610	C=C (Aromatic ring)	8, 9,45
1610	-	-	Iron phosphate	8, 9
-	1436	1436	C-H bending	8, 9,45
-	1382	1382	CH ₃ bending vibration	40,45
1272	-	1272	Stret. P=O	8, 9
-	1249	1247	Epoxy & oxirane rings	42,45
-	1172	-	Stret. vibration of ether linkage (C-O)	37,42
-	1041	-	Stret. vibration of C- O	41,42
1024	-	-	Iron phosphate	8, 9
-	-	1020	Fe-plant extract complex/ salt	8, 9
663	-	663	γ -Fe ₂ O ₃	8, 9
The peaks between 400 -700 cm ⁻¹ mainly due to Fe ₂ O ₃				8, 9

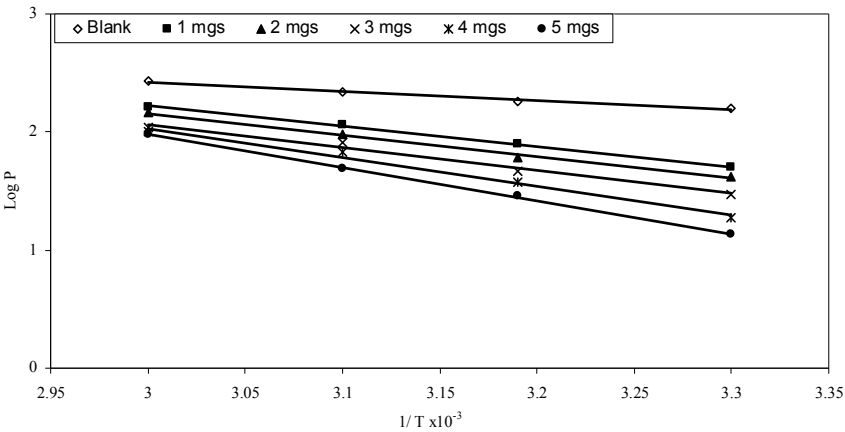


Fig. 1. Arrhenius Plot for Corrosion in 1N Phosphoric acid with AIAE

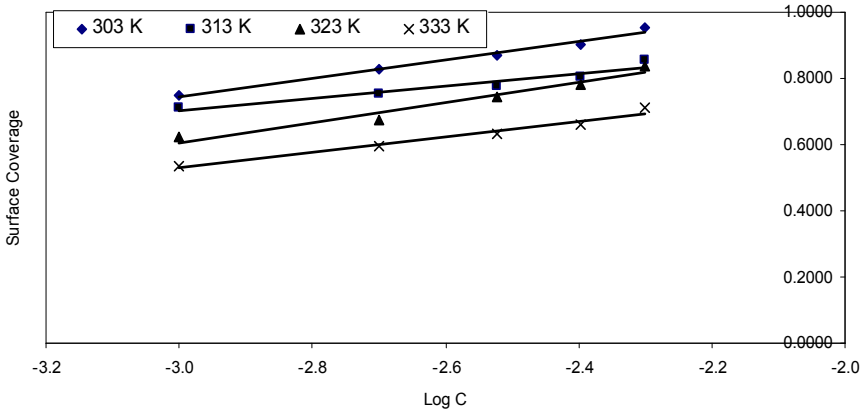


Fig. 2.Tempkin's adsorption isotherm for corrosion behaviour of mild steel in 1N Phosphoric acid with AIAE

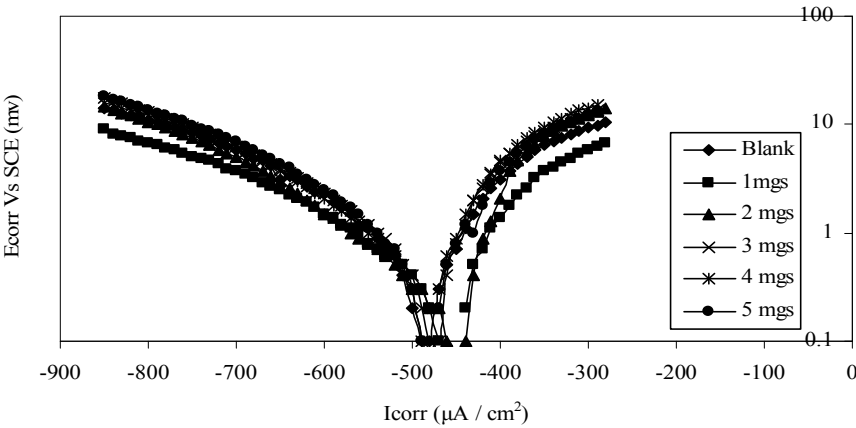
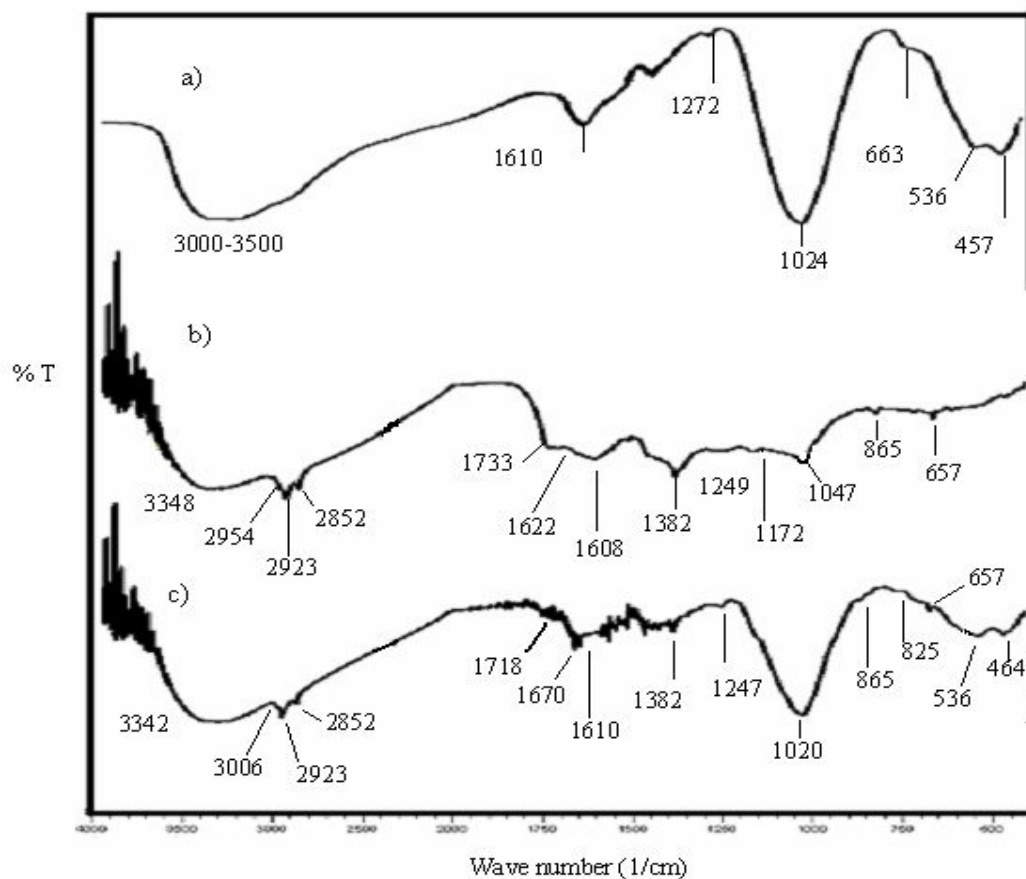
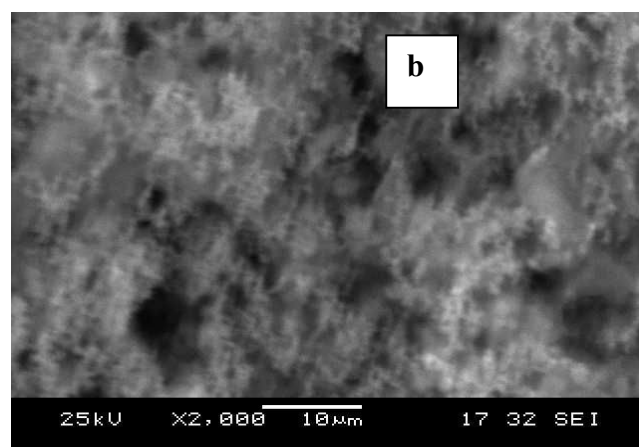
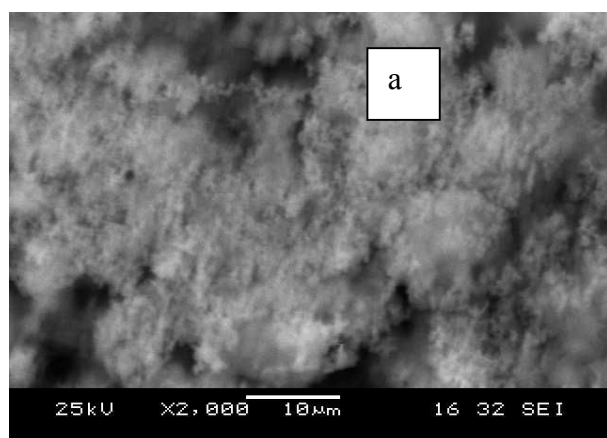


Fig. 3. Typical Potentiostatic curves for mild steel in 1N Phosphoric acid with AIAE



**Fig: 4. FT-IR spectrum of a) Mild steel in 1N Phosphoric acid. b) Plant extract (AIAE)
c) Mild steel in 1N Phosphoric acid with AIAE**



**Fig: 5. SEM analysis of a) Mild steel in 1N Phosphoric acid
b) Mild steel in 1N Phosphoric acid with AIAE**

Conclusion

The following conclusions were made from the studies,

1. Corrosion rates of mild steel in 1N phosphoric acid decreased with increasing concentration of AIAE.
2. The inhibition efficiency increased with respect to the concentration of inhibitor and decreased with rise in temperature from 303K to 333K.
3. The maximum inhibition efficiency of AIAE was found to be 95.21% and 90.38% in 1N phosphoric acid at 5mgs of inhibitor from mass loss studies and polarization measurement respectively at 303K.
4. The inhibition efficiency obtained from mass loss and polarization measurement showed fairly good agreement.
5. Energy of activation (E_a) values indicated that the addition of plant extract hinders metal dissolution and also indicated that, decrease in the adsorption of the inhibitor on mild steel surface with increase in temperature.
6. The negative value of ΔG_{ads} indicated that the AIAE is chemically adsorbed and spontaneous adsorption of inhibitors on the surface of mild steel.

7. The higher negative values of heat of adsorption also showed that the inhibition efficiency decreased with rise in temperature
8. The high positive enthalpy values of adsorption (ΔH_{ads}) evident that the plant extract strongly adsorbed on mild steel is probably chemisorption.
9. The gain in entropy that accompanied by the substitutional adsorption process was attributed to the increase in solvent entropy.
10. It is found that the AIAE acting as mixed type inhibitor.
11. The adsorption of AIAE on mild steel surface from the acid solution followed Temkin's adsorption isotherm.
12. FT-IR and SEM analysis showed the presence of compounds in the plant extract react with metal ion to form the layer of inhibitor on the metal surface.

Acknowledgement:

We thank Dr.K.Srinivasan, Head, Department of Chemistry, Govt. College of Engineering, Salem -11 for his kind encouragement in pursuing this work.

References

1. A. C. Hart, *Br Corros. J.*, **6**, 205 (1971).
2. A. C. Hart, *Br Corros. J.*, **8**, 66 (1973).
3. R. M. Saleh, M. M. Badran, A. A. Alhosary, and H. A. El Dahan, *Br Corros. J.*, **105** (1988).
4. F. Smith and N. H. Van Droffeleaer, *Br Corros. J.*, **26**, 265 (1991).
5. A. M. Al -Mayot, A. A. Al-Suhybani, and A. K. Al -Ameer, *Desalination.*, **25**, 116 (1998) and references therein.
6. S. L. Granese, B. M. Rosales, C. Oviedo, and J. O. zerbino, *Corros. Sci.*, **33**, 1439 (1990).
7. V.Chandrasekaran, K.Kannan,M.Natesan, *Corrosion Science and Tech.*, **4**,191-200 (2005).
8. G.Gunasekaran and L.R.Chaughan, *Electrochemical Acta.*, **49**, 4387-4395 (2004).
9. A.M.Abdel-Gaber, B.A.Abd-El- Nabey, I.M.Sidahamed, A.M.El-Zayady, M.Saadawy, *Corrosion Sicience.*, **48**, 2765-2779 (2006).
10. S. Rajendran, V.Ganga Sri, J. Arockiaselvi and A. John Amalraj *Bull. of Electro chemistry.*, **21**(8) 367-377 (2005).
11. K.O.Orubite and N. C. Oforka, *Materials Letters.*, **58**, 1768-1772 (2004).
12. Emeka E.Oguzia, *Materials chemistry and Physics.*, **99**, 441-446 (2006).
13. P.C.Okafor, U.J. Ekpe, E. E. Ebenso, E. M. Umoren, and K .E. Leizou, *Bull. Of Electrochem.*, **21**(8), 347-352 (2005).
14. M.Kalpna and G.N.Mehta Transacutions of the *SASET.*, **38**, 40-42 (2003).
15. A.Y.El-Etre,M.Abdallah,Z.E.El- Tantaway *Corros. Sci.*, **47**, 385-395 (2005).
16. Sha Cheng, Shougang Chen,Taoliu,Xueting Chang, Yansheng Yin , *Materials Letters.*, **61**, 3267-3280 (2007).
17. A.Nahrstedt, M.Hungeling, F.Petereit , *Fitoterapia.*,**77**,484-486,(2006).
18. Annie Shirwaikar, K.Rajendran, Ramgopal Bodla, C.Dinesh Kumar., *Journal of Enthopharmacology* .,**94**,267-273 (2004).
19. S.P.Hiremath, K.Rudresh, B.Shrishailappa., *Indian Journal of Hetero cyclic chemistry* (communicated) (1998)
20. K.K.Purushothaman., S.Chandrasekharan, K.Kalyan., *Journal of Res.Indian Med*, **8**,50, (1973).
21. M.A. Quraishi, M. A. W. Khan, M. Ajmal and S. Muralitharan, and S. V. Iyer, *Br. Corros. J.* **53**, 475(1997).
22. ASTM G 31 – 72, “Standard Practice for labortary Immersion Corrosion Testing of Metals”, West Conshohocken, PA; ASTM (1990).

23. M.A. Quraishi, M. A. W. Khan, *Indian Journal of Chemical Tech.*, **12**, 576-581 (2005).
24. V.Chandrasekaran, K.Kannan, M.Natesan, *Corrosion Science and Tech.*, **4**,191-200 (2005).
25. G.Gunasekaran and L.R.Chaughan, *Corrosion Science.*, **49**, 1143-1161 (2007)
26. F.Bentiss, M.Bouanis, M.Traisnel, H.Vezin, M.Lagrennee, *Applied surface science.*, **253**, 3696 - 3704 (2007).
27. T.Szauer and A.Brand, *Electrochemical Acta.*, **26**, 1219 (1981)
28. M.Bouklah, B. Hammouti, M.lagrennee. F.Bentiss, *Corrosion science.*, **48**, 2831-2842 (2006).
29. Weihua Li, Qiao He, Changling Pei, Baorong Hou, *Electrochemica Acta.*, **52**, 6386-6394 (2007).
30. E.E.Oguzie, *Materials chemistry and Physics.*, **87** 212-217 (2004).
31. V.Chandrasekaran, K.Kannan,M.Natesan, *Journal of metallurgy and material Science.*, **46**, 253 (2004).
32. I.N. Putilova, V.P Barannik, S.S. Balezin, *Metallic Corrosion Inhibitors*, Pergamon Press, Oxford **30** (1960).
33. O.O. Adeyen, *Bulletin of Electrochemistry.*, **21** (9) 363 -366 (2005).
34. B. Ateya, L. Callow and J. Dawson, *Br.Corros. J.*, **15**, 20 (1980).
35. N. Hackerman, *corrosion.*, **18**, 332 (1962).
36. B.G. Atya, B.E. El-Anadouli and F. M. El-Nizamy, *Corros, Sci.*, **24**, 497(1984).
37. X.L. Cheng, H.Y. Ma.Ma, S.H. Chen, R.Yu, X. Chen and Z.M. Yao, *Corros., Sci.*, **41**, 321 (1999).
38. O. Lkeda, H. Jimbo and H. Jaumura, *J. Electroanal. Chem.*, **137**, 127 (1982).
39. R. Pearsons, *J. Electroanal, Chem.*, **7**, 136 (1964).
40. J.O.M. Bockris and D.AJ. Swinkkels, *J. Electrochem, Soc.*, **11**, 736 (1964).
41. B. Atya, B. El-Anadouli and F. El-Nizamy, *Corros, Sci.*, **24**, 504, (1984).
42. G.Gunasekaran and L.R.Chaughan, *Corrosion Science.*, **49**, 1143-1161 (2007).
43. Susai. Rajendran, B.V.Apparao, N.Palanisamy, *Electrochemica Acta.*, **44**, 533-537(1998).
44. B.V. Apparao and K.Christina, *Indian Journal of Chemical Tech.*, **13**, 275-282 (2006).
45. R.A. Meyers,John Coates "Interpretation of Infrared spectra, A practical approach" in Encyclopedia of analytical chemistry pp: 10815-10837
46. T.Kumar, S.Viswanathan and J. Emaranuzzaman, *Indian Journal of Chemical Tech.*, **15**, 221-227 (2008).
